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ABSTRACT

Regression formulations and related concerns involved in dealing with wage discrimination suits involving college faculty are considered. Several models based in hypothesis testing "policy capturing" uses of multiple linear regression are presented, and problems related to the court's view of statistical significance are examined. Multiple linear regression can be used to determine if there is a policy operating in the hiring process, and if so, to capture it and evaluate it in terms of R2 (R to the power of 2). The process is to add variables to the model explaining the decision to hire or not to hire until a high level of R2 is achieved, evaluate the weighting coefficients to determine the emphasis given each variable, and then test for significance using the F test, which is described. In the event that the plaintiff has introduced a regression model that shows gender to be a statistically significant contributor to salary and particularly if the institution is large, so that virtually any element related to salary will have some degree of statistical significance, a useful strategy is to introduce similar models based on more appropriate assumptions about the group to be studied. Regressions by rank or based on members of only those departments that have both males and females are alternative approaches. Another approach is to study the effect that gender has had on salaries over some interval of time. A repeated measures model can help determine whether corrective measures reduced differences in salary that can be attributed to gender for individuals who were in the system over a given period of years. The issues of statistical versus practical significance, denominator degrees of freedom, and future use of a path analytic approach are considered. (SW)

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USING REGRESSION ANALYSIS TO CAPTURE POLICY IN A GENDER DISCRIMINATION SUIT

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This paper was presented at the Twenty-First Annual Forum of the Association for Institutional Research held at the Leamington Hotel in Minneapolis, Minnesota, May 17-20, 1981. This paper was reviewed by the AIR Forum Publications Committee and was judged to be of high quality and of interest to others concerned with the research of higher education. It has therefore been selected to be included in the ERIC Collection of Forum Papers.

Mary Corcoran
University of Minnesota
(Editor, AIR Forum Publications)

ABSTRACT

This paper presents some regression formulations and related concerns involved in dealing with wage discrimination suits. Several models based in hypothesis testing-policy capturing uses of multiple linear regression are presented. The paper also discusses problems related to the court's view of statistical significance.

USING REGRESSION ANALYSIS TO CAPTURE POLICY IN A GENDER DISCRIMINATION SUIT

This paper discusses some regression formulations and concerns covered more broadly in "The Role of the Institutional Researcher in a Sex Discrimination Suit". In the course of discussion, we will present some models for addressing several court related issues. The models are based in hypothesis testing and policy capturing approaches to multiple linear regression.

To a court, a regression analysis is evidence entered to substantiate an argument, usually one dealing with a question of what Baldus and Cole (1980) call, "The cause and consequences of practice alleged to be discriminatory". In other words, courts tend to view regression analysis as a method for capturing past policy.[1] Further, if a regression analysis is entered in a suit for discriminatory treatment, it is likely done so by the plaintiff, leaving the defendant no choice but to respond in kind (Simpson and Rosenthal, 1981). The defense would need to respond with a regression model using those factors logically involved in determining salaries which shows that gender does not contribute significantly to the overall result. Such a regression procedure takes a statistical "picture" of the faculty salary situation at a precise moment in time. In addition, we will explore in this paper a somewhat different process, namely a dynamic use of regression to capture changes in the salary structure over a time interval, the purpose being to detect or document changes that could reasonably be expected to result from a certain pre-determined policy or some change in policy.

One might anticipate that adoption of a formal policy of affirmative action would cause detectable compensation changes. Whether those changes would be most apparent as measured by salary variance, mean or median salary, a separate salary index (Gastwirth, 1975) or some other measure is subject for discussion in its own right, which we will not attempt here. For discussion

purposes, we shall call the criterion variable "actual salary" unless otherwise noted. The change we would hope to capture (assuming a problem exists) would be from some less desirable state before the implementation of (affirmative action) policy to some more desirable state after the policy.

Policy capturing (McNeil, Kelly and McNeil; Christal; Newman and Benz) is a conceptual approach to measuring change. It is usually treated as an application of hypothesis testing uses of Multiple Linear Regression. These approaches and the F test used for them (also see Morse, 1978) are similar enough to stepwise procedures that one would not expect the two methods to produce radically different results; however, in terms of articulating questions or hypotheses and explaining results to lay audiences the hypothesis testing-policy capturing approaches may be particularly useful.

Policy capturing suggests that any predictor (independent) variable which contributes to the variance in the criterion (dependent) variable, when the criterion is a result of a decision, is an element in the making of that decision, a view very similar to that stated in Baldus and Cole and similar to our perception based on the case we have observed. The importance of that element has been treated as a statistical matter (significant F) in a number of court cases. We would contend that importance is also a matter of ΔR^2, a matter we will discuss below. Change in R^2 as a measure of "practical significance" (McNeil, Kelly and McNeil) or "net import" (Baldus and Cole) is a matter which could be explored with the defendant's (we assume that institutional researchers will be in that role) lawyers as part of a possible ground rules agreement for the entering of any regression formulation. Focusing on ΔR^2 may satisfy Baldus and Cole's warning that a defendant's regression variables may be questioned if their addition only reduces α but not net import (see also McNeil, Kelly and McNeil) and may satisfy certain objections raised relative to problems of multicollinearity (Ramsay, 1979; Baldus and Cole).

In describing policy capturing approaches, Christal; McNeil, Kelly and McNeil and Newman and Benz stress the attempt to achieve a high R^2 in order to ensure that the largest possible number of explanatory variables have been included. McNeil, Kelly and McNeil present an analysis of a hiring situation as an example, asking how one might trace out the "policies", conscious or not, applied by those responsible for hiring new teachers. They point out that individuals are usually not capable of incorporating all the information available to them nor of articulating "the policy" which operates in the hiring process. "Multiple-linear regression can be used to determine if there is a policy, and if there is one, to capture it, and once captured evaluate it in terms of R^2" (McNeil, Kelly and McNeil). The "captured" policy can then be applied (or modified to correct problems) to future hiring processes. The process, broadly described, is to add variables to the model explaining the decision to hire or not to hire until a high level of R^2 is achieved, evaluate the weighting coefficients to determine the emphasis given each variable (standardized coefficients make the comparison easier when the criterion is categorical) then test for significance using the F test described below.

Hypothesis testing regression approaches have been discussed in a number of sources (McNeil, Kelly and McNeil, Ward and Jennings, Bottenberg and Ward). In general, they describe a process of testing a null hypothesis by comparing a "full" regression model against a "restricted" model (the full model minus one or more variables). The comparison of the two models essentially indicates how likely it is that the difference between R^2_f and R^2_r is due only to sampling error; this question is answered by an F test in which

$$F = \frac{(R^2_f - R^2_r)/dfn}{(1 - R^2_f)/dfd}$$

where:

$R^2_f = R^2$ of the full model

R^2_r = R^2 of the restricted model

dfn = the number of linearly independent variables in the full model minus the number of linearly independent variables in the restricted model ($M_1 - M_2$)

dfd = N minus the number of linearly independent variables in the full model ($N - M_1$) when M_1 includes the unit vector, otherwise ($N - K - 1$)

(McNeil, Kelly and McNeil, also discussed briefly in SPSS manual).

Hypothesis Dealing with a Specific Policy Issue

In a complicated situation, as are all wage equity discussions--especially court related ones--it is important to be able to go one step further and to ask whether certain variables are part of the decision making process over and above the effects of variables believed to have a legitimate part in the process. The general form of this issue cast as an hypothesis would be as follows:

Some illegal or illogical (illegitimate) concerns (age, gender, 504 status, etc.) are significant contributors to the decision process over and above the logically and legally defensible (legitimate) set of concerns (education, talent, experience, etc.) which enter into the decision to reward workers. By testing the full model (see below) against a restricted model which comprises the "legitimate" variables, one is testing the effects of the variables under question against a salary that is already adjusted to reflect the "legitimate" individual characteristics; this is a realistic approach and one which is close to that which is implied but often unstated in stepwise formulations. A limitation of some stepwise regression work is that the hypothesis is a generalized one, usually unstated, which may or may not apply but whose generality makes that assessment difficult.

McNeil, Kelly and McNeil list as steps in the hypothesis testing process the statement of (1) a research hypothesis, a statement about the population which the researcher hopes to support; and (2) a statistical hypothesis, the

antithesis of the research hypothesis. In that format, then, a related hypothesis looks like this:

Research Hypothesis:

Salary is not a function of gender over and above degree, time in rank, and tenure status[2] (or, stated alternatively, gender is not a significant predictor of salary over and above the effects of degree, time in rank, and tenure status).

Statistical Hypothesis:

Gender is a significant predictor of salary over and above the effects of degree, time in rank, and tenure status.

The models representing this statistical hypotheses are these:

1. Full Model:

   Salary = U + Degree + Yrnk + Appt + Gender + E

2. Restricted Model:

   Salary = U + Degree + Yrnk + Appt + E

Where

U = the unit vector

Degree = highest degree held

Yrnk = years in current rank

Appt = tenure status

E = variance not accounted for

R^2 and Alpha

Should a plaintiff successfully enter into evidence the results of a standard SPSS stepwise regression salary model based on data from selected departments for a given period (in our example let us assume a model R^2 of .50 and significant F ratios for each variable, one of which is "gender"), the plaintiff may claim that it has proved that the institution discriminates on the basis of gender. The evidence in that case suggests that, for certain units,

gender and other selected variables are statistically significant contributors to differences in salary, but the hypothesis, which has not actively been tested, appears to be that gender is a significant contributor over and above legitimate variables. In such a case, the defendant is challenged to develop a regression model which shows some other result, that is, to formulate alternate hypotheses or to reaggregate the population, processes we suggest that may not be entirely clear to many of the participants in a court case.

If the variable in question is an important contributor to the R^2 and is statistically significant, the results are clear (the gender variable has a strong influence on salary). In contrast, it frequently happens that the gender variable is statistically significant, but the R^2 change attributed to it is small. In such cases the most accurate interpretation is "Gender is a statistically significant but very minor contributor to the variance in salary accounted for by the full model"; this full statement is often reduced in court to a much abbreviated and potentially misleading form (particularly to non-statisticians: "Gender is a statistically significant contributor."

One of the problems in this sort of presentation is that the distinction between statistical significance and "practical" significance (McNeil, Kelly and McNeil) does not appear to be fully appreciated in at least some court cases. The word "significance" (as in "statistical significance") may be the culprit, leading those not trained in research away from the simple idea that something other than chance is operating to the idea that this is an element of great importance.

Statistical significance is a necessary but not sufficient condition for practical significance. The large N in a wage suit in a large university may virtually guarantee statistical significance to very small differences in salaries while relatively large differences in a smaller institution would not generate statistical significance. Indeed, it is possible to imagine a

situation in which Large State University (faculty = 2000) loses a court case because plaintiffs received a statistically significant $30 per year less than members of another group while Small Valley College (faculty = 150) with a salary difference of $1000 per year wins its case because the difference is not statistically significant. Table I displays the results of the same model calculated for faculty of varying sizes. (Just as lawyers for both sides will likely argue for an inclusion level [.05 is most probable], from the researcher's view, some prior ground rules on acceptable lower bounds for R^2 accounted for by a given variable or set of variables could also be an issue for negotiation. This is a point which may not come easily, though.) The visual tracing out of full and restricted models may also function as an effective communications device for tracing out that difference.

In the event that the plaintiff has introduced a regression model (in one of its forms) which shows gender to be a statistically significant contributor to salary and particularly if the institution is a large one, so that virtually any element related to salary will have some degree of statistical significance (as above), a useful strategy is to introduce similar models based on more appropriate assumptions about the group to be studied. Regressions by rank (McCabe and Anderson, 1976) will produce more useful results than regressions on the faculty as a unit. Similarly, regressions based on members of only those departments which have both males and females give a truer picture and certainly will give a quite different picture from the one presented by a study of the entire faculty, particularly in cases in which the university comprises single sex and integrated departments. Certainly such changes in focus will reduce the denominator degrees of freedom and, thus, the likelihood of statistical significance. Table I illustrates the results of viewing units of different size and, thus, denominator degrees of freedom and significance. In the extreme cases of the large university and the smallest college in Table I, for

each of several ΔR^2's (.01, .001, etc.), the small college is never "guilty" if statistical significance is the measure; the large university is almost always "guilty". As the R^2 changes become smaller, there is a case in which no institution is "guilty" save for the large one, even though the magnitude of the offense is, in all cases, the same. We are not suggesting that researchers create arbitrary groupings to change denominator degrees of freedom, but this inevitable result of legitimate shifts in the focus of a particular analysis must be considered.

Insert Table I about here

Searching for Evidence of Real Change as a Result of a Formal Institutional Policy Change

Another, somewhat different, approach is to study the effect that gender has had on salaries over some interval of time. This can be done by taking a statistical snapshot at the beginning and end of the time period (or at regular points throughout) and then comparing the results. Such a procedure would provide support to the claim that the underlying policy over the time period under study has caused a diminishing of gender bias. This would be a particularly effective way to demonstrate that personnel policies put into effect at some well defined point (say, for example, after the enactment of Title IX Education Amendments Act in 1972) have been effective in correcting past injustices. At the very least, it would show good intent on the part of the institution. The following example provides further details:

The task is to show that gender has less influence on salary in 1975 than it did in 1972 when Title IX went into effect.

Research Hypothesis for 1972 Data:

For assistant professors hired during 1972 gender is not a statistically significant contributor to wage decisions, as represented by actual salary, over

and above the effects of other contributors to the decision process.

Statistical Hypothesis:

Gender is a statistically significant contributor to salary over and above the effects of other contributors to the decision process.

Full Model:[3]

$$\text{Salary} = U + \text{Mon} + \text{Yten} + \text{Yrnk} + \text{Appt} + \text{Yrk}^2 + \text{Ytn}^2 + \text{Age}^2 + \text{Gender} + E^4$$

Restricted Model:

$$\text{Salary} = U + \text{Mon} + \text{Yten} + \text{Yrnk} + \text{Appt} + \text{Yrk}^2 + \text{Ytn}^2 + \text{Age}^2 + E$$

where

U = unit vector

Mon = appointment month

Yten = years in tenure system

Appt = appointment (tenure system) status

Yrk^2 = years in rank squared

Ytn^2 = years in tenure system squared

Yrnk = years in present rank

Gender = 1 if male, 0 otherwise

E = variance not accounted for

Example results:[5]

$R^2_f = .64604$

$R^2_r = .63028$

$dfn = m_{\text{.}} - m_2^6 = 7 - 6 = 1$

$dfd = n = m_1^7 = 192 - 6 = 186$

$$F = \frac{.64604 - .63028/1}{(1 - .64604)/186} = \frac{.01576}{.00190} = 8.29 \quad \alpha = .000$$

The change in R^2 attributable to knowledge of gender is approximately .016 (or 1.6% of the variance in salary). The practical significance of such a small

R^2 is relatively modest and could be argued. Such a model repeated for groups hired over a series of years would allow an eyeball test for diminishing ΔR^2's and diminishing F's.

Example:[8]

Year Hired	ΔR^2	F	
1970	.055	28.6	statistically significant at or above .05
1971	.016	8.3	
1972	.010	5.2	
Title IX Implementation			
1973	.006	3.1	not statistically significant at or above .05
1974	.001	0.52	
1975	.0007	0.36	

Such a display would lend support to the argument that implementation of an affirmative action policy has diminished the role of gender to insignificance in both the statistical and practical senses. If the institution has also made equity adjustments to salaries for certain individuals hired prior to policy changes, R^2 differences in gender will be smaller than one might anticipate. Indeed, if the equity adjustments have been highly successful, the pre-change group may show smaller R^2 for gender than does the post-change group. If this is the case, testing the pre-change group's salary before and after the change will be useful.

Repeated Measures Model: Another Approach to Testing for the Effects of a Change in Policy

One method for doing so is a repeated measures model (i.e., a model designed for statistical rather than eyeball comparisons and which follows the same group of individuals over time (Ramsay) that responds to this question: Have corrective measures reduced differences in salary which can be attributed to gender for individuals who were in the system over a given period of years? To

counteract the effect of rising salaries, the criterion measure can be changed to standardized deviation scores or salaries corrected to constant dollar figures. The latter has the advantage of keeping the criteria in dollar terms.

Research Hypothesis:

The genders are different over the X measurement periods over and above individual differences.

Statistical Hypothesis:

The genders are the same over the X measurement periods over and above individual differences.

Full Model:

$$\text{Salary} = U + (M \times T1) + (F \times T1) + \ldots (M \times Tn) + (F \times Tn) + P1 \ldots + Pn + E$$

Restricted Model:

$$\text{Salary} = U + M + F + T1 + \ldots Tn + T1 \ldots + Pn = E$$

where

U = the unit vector

T1 = 1 if the salary is from measurement period 1, zero otherwise

Tn = 1 if the salary is from measurement period n, zero otherwise

M = 1 if the salary is from a male, zero otherwise

F = 1 if the salary is from a female, zero otherwise

P1 = 1 if the salary is from person 1, zero otherwise

Pn = 1 if the salary is from person n, zero otherwise

E = variance not accounted for

This method has the advantage, through the use of person vectors, of increasing the amount of variance accounted for by such a large degree of magnitude that it offsets the resulting loss in denominator degrees of freedom (McNeil, Kelly and McNeil). It has the disadvantage of requiring space in the model for each subject, meaning that only units of a limited size may be studied unless one

has control over the computer package (as in Veldman). The F produced is exactly equivalent to the more traditional analysis of variance repeated measures design (Rosenthal and Spaner, 1978).

Policies Over Which the Institution has Little or No Control

One critical problem that arises in any investigation of wage issues in a university is that of market value and gender-tradition within disciplines, hence within departments. An essential question is one of the degree to which wage differences are based in practices of which the university has had no control (an issue quite different from that of whether universities have played a broad role in long term discriminatory processes). Raising this question becomes, in terms of the most general hypothesis: As part of the set of policies which govern wage decisions, there is a subset over which the university has no direct control (or, perhaps, had no direct control prior to some specific date on which affirmative action plans were implemented).

An approach to this issue is to test the hypothesis that salary differences are related to both gender and department. One method of setting up the test would be as follows:

Research Hypothesis:

Knowing both the gender and the department affiliation of a faculty member enables one to significantly improve upon the salary prediction for that member.

Statistical Hypothesis:

Knowledge of gender and department is not a significant predictor of salary over and above knowledge of department alone and other "legitimate" predictors.

Full Model:

$$\text{Salary} = U + \text{Rank} + \text{Age} \ldots + \text{Dept A} + \text{FDept A} + \ldots + \text{Dept Z} + \text{FDept Z} + E$$

Restricted Model:

Salary = U + Rank + Age ... + Dept A ... + Dept Z + E

where

U = unit vector

Dept A = 1 if a member of department "A", zero otherwise

FDept A = 1 if a female member of department "A", zero otherwise

Dept Z = 1 if a member of department "Z", zero otherwise

FDept Z = if a female member of department "Z", zero otherwise

E = variance not accounted for

Further, the results of this model could be investigated one department at a time to attempt to isolate significant biases within any given department.

A caveat for all the above models, untreated, we believe, in the legal literature, is that each F test performed on the same sample changes the odds for chance occurrence. Newman and Fry, 1972; and Connett, 1971, discuss the increases in α over a series of tests necessary to maintain the initially chosen level.

Finally, a number of our discussions have lead us to suspect that some questions about the relationships among variables (sex and rank, for instance) may lend themselves to a path analytic approach (McLaughlin, Smart and Montgomery, 1978). This is not to suggest courts are currently prepared to cope with path analysis but that researchers may be able to use it to trace out certain issues which are fundamental to the regression formulations the court may require. The graphical display usually associated with a path analysis would probably have a strong impact in a courtroom. Such a visual trace of inter-relationships might make more sense than a technical discussion to a layman.

FOOTNOTES

[1]"Policy" in this sense is akin to what "practice" is often used to mean: that which really happened. It does not require that formal or written statements of policy exist, although it does not exclude them.

[2]Inclusion of so small a number of variables is for the purpose of simplifying the example.

[3]This is not meant to be viewed as a complete salary model. It is presented in this abbreviated form for example purposes.

[4]We have eliminated the notation for weighting coefficients from the model for simplicity of presentation.

[5]These results are not intended to reflect actual results relative to any court case now pending.

[6]Degrees of freedom, numerator = the number of linearly independent variables in the full model minus the number of linearly independent variables in the restricted model.

[7]Degrees of freedom, denominator = N minus the number of linearly independent variables in the full model.

[8]See notes for previous example.

TABLE I

R^2 Full model = 0.85

$$F = \frac{(0.85 - \quad)/1}{(1 - 0.85)/N - 11}$$

Inst.	N (denominator)	Tabled F at appropriate degrees of freedom necessary for .05 significance	ΔR^2 .01	.001	.0005	.0001
A	1500 (0.00010074)	(3.84)	99.265	9.927	4.96	0.993
B	1000 (0.00015167)	(3.85)	65.933	6.593	3.30	0.659
C	500 (0.00030675)	(3.86)	32.600	3.260	1.63	0.326
D	250 (0.00062762)	(3.89)	15.933	1.593	0.80	0.159
E	150 (0.00107914)	(3.92)	9.267	0.927	0.46	0.093
F	50 (0.00384615)	(4.09)	2.600	0.260	0.13	0.026

A comparison of size of faculty effect on statistical significance for ΔR^2 .01 to .0001

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